



US 20100242559A1

(19) **United States**(12) **Patent Application Publication**
SAENZ de MIERA(10) **Pub. No.: US 2010/0242559 A1**(43) **Pub. Date: Sep. 30, 2010**(54) **METHOD OF PRODUCING ALUMINUM PRODUCTS****Publication Classification**(76) **Inventor:** Vicente Martin SAENZ de MIERA, Jaca (ES)(51) **Int. Cl.**
B21H 8/00

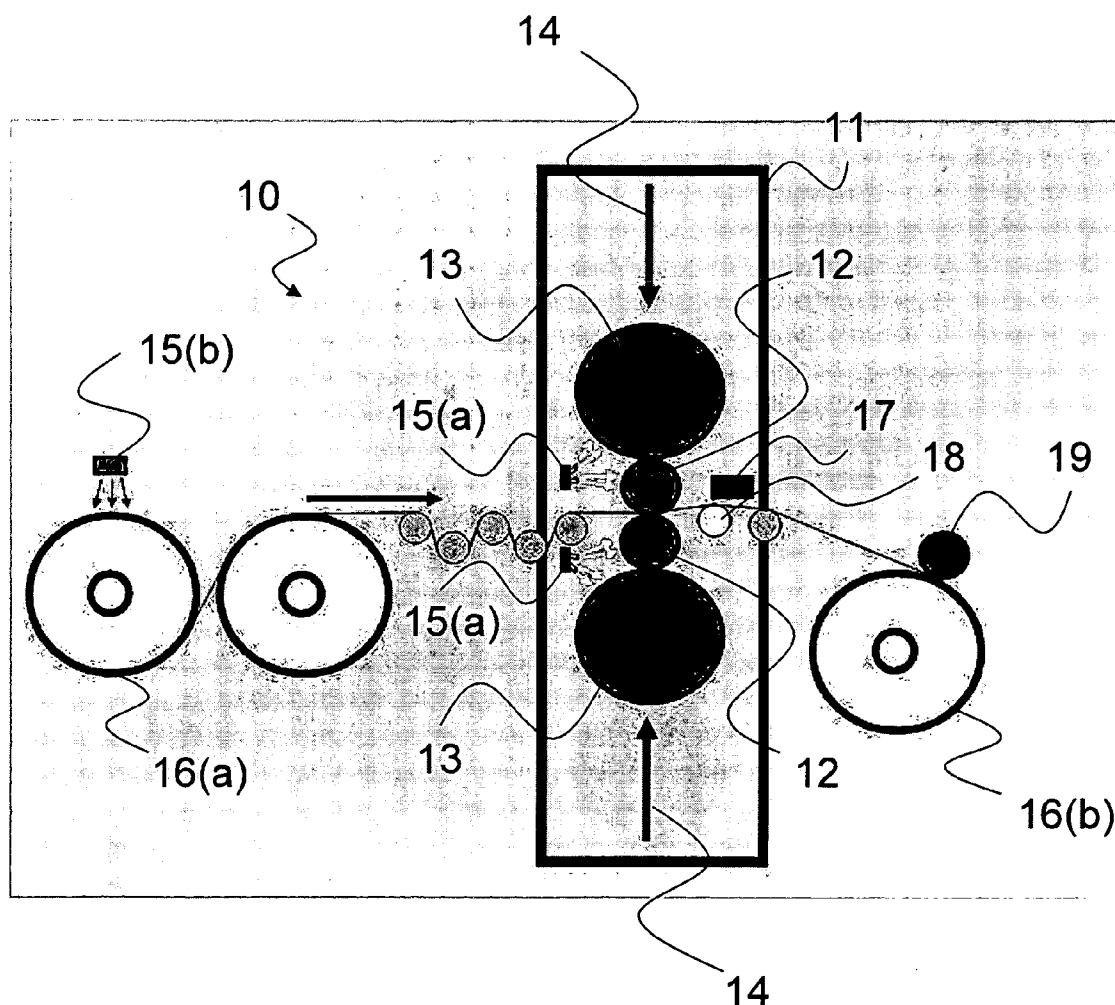
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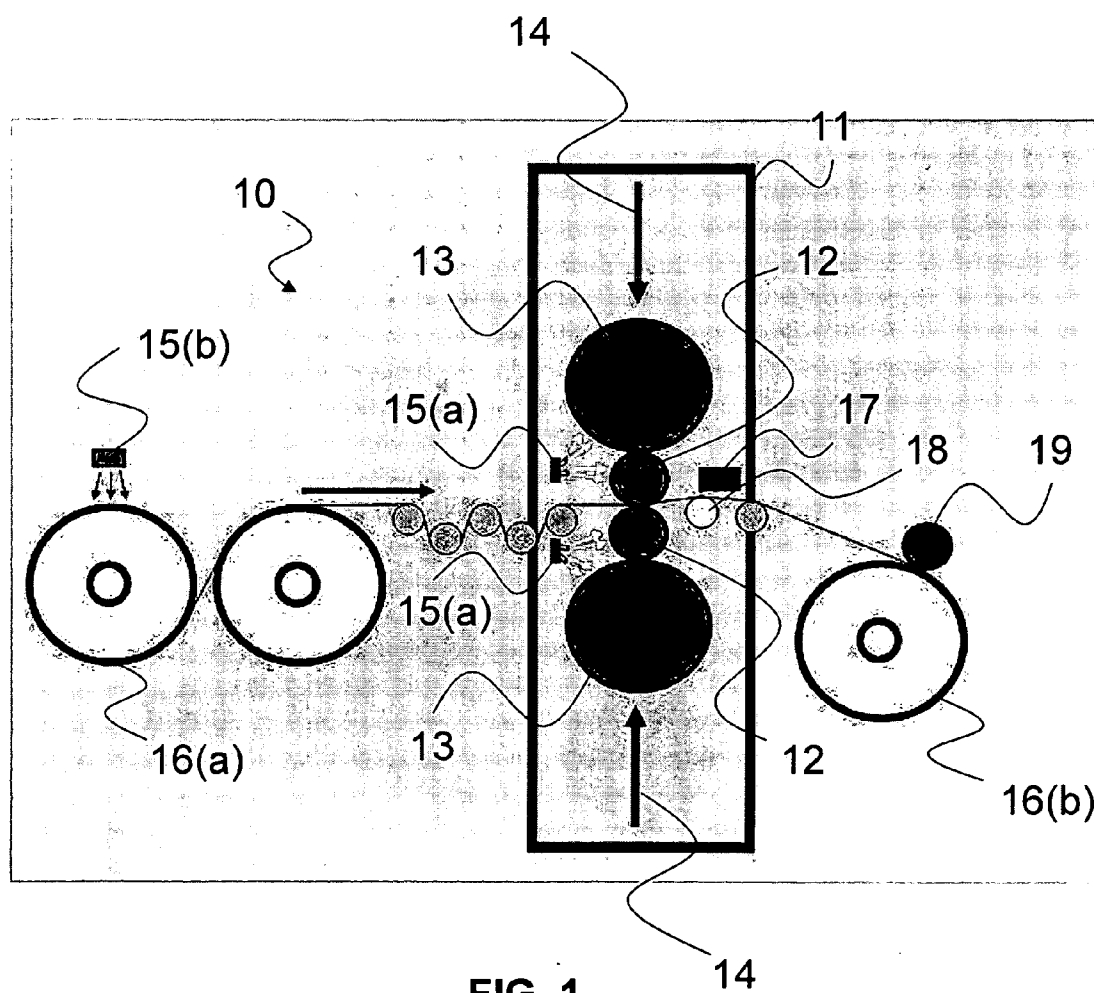
(52) **U.S. Cl.** 72/207(57) **ABSTRACT**

Correspondence Address:

INTELLECTUAL PROPERTY
ALCOA TECHNICAL CENTER, BUILDING C,
100 TECHNICAL DRIVE
ALCOA CENTER, PA 15069-0001 (US)

Methods of producing pack rolled aluminum products by contacting bright finishes of two strips with each other, contacting matte finishes of each strip to a pair of work rolls, and rolling the strips through a sheet and foil rolling mill are disclosed. Concomitant to the contacting step is lubricating at least one of the bright finishes of the two strips. Each strip can achieve a reduction in thickness of at least about 65% after the rolling step.

(21) **Appl. No.:** 12/409,635(22) **Filed:** Mar. 24, 2009



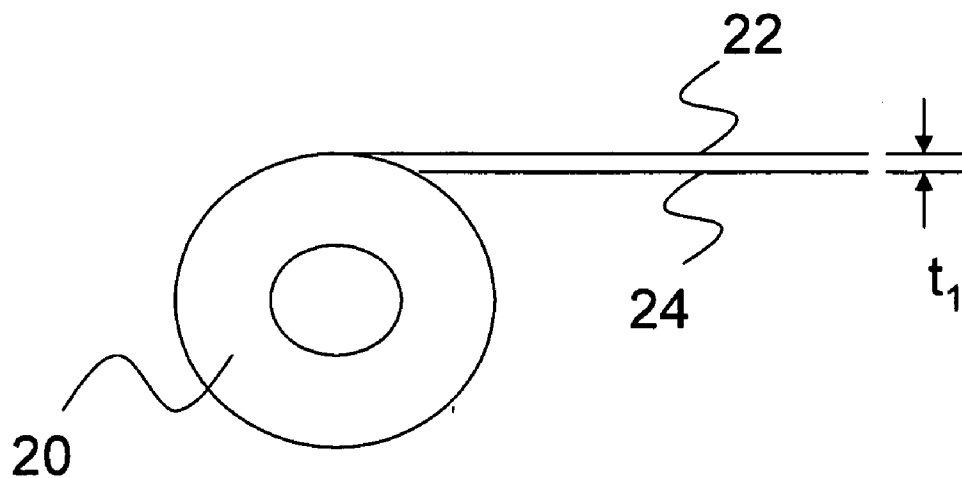


FIG. 2(a)

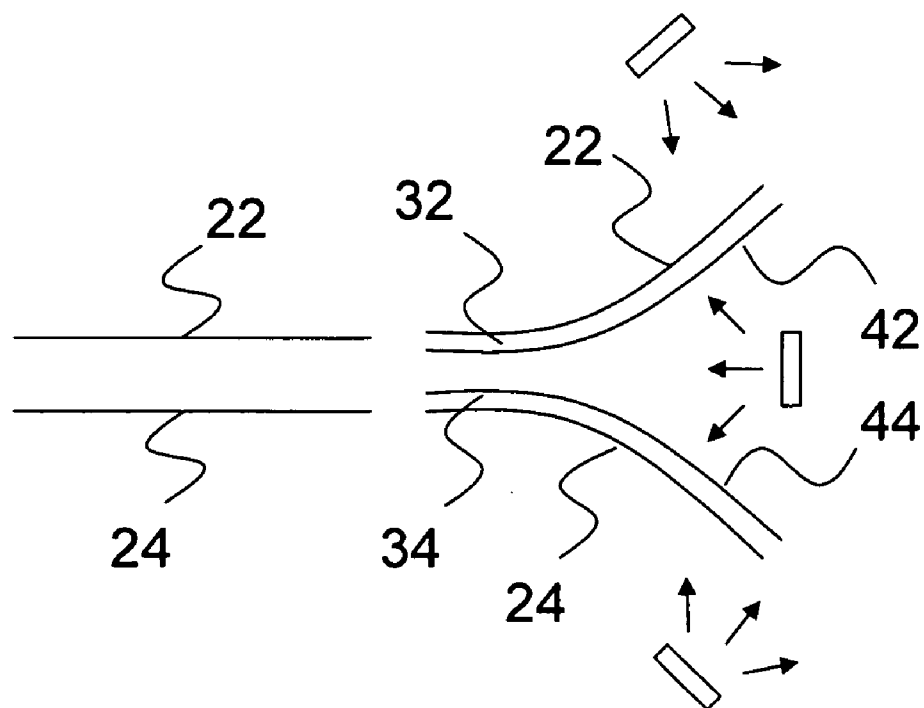


FIG. 2(b)

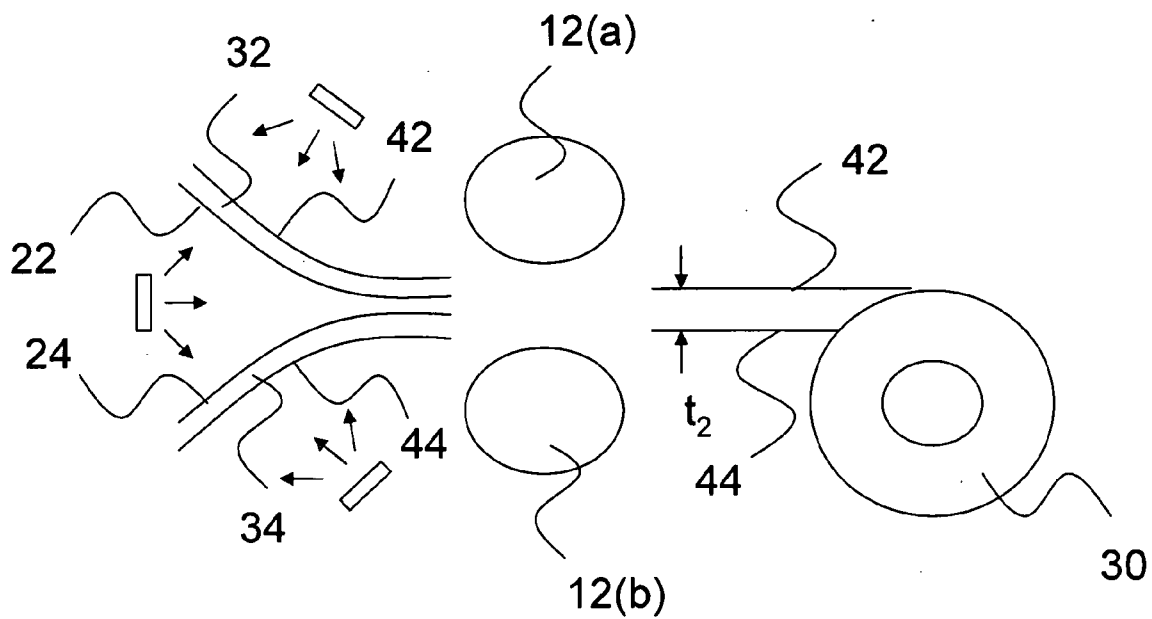


FIG. 2(c)

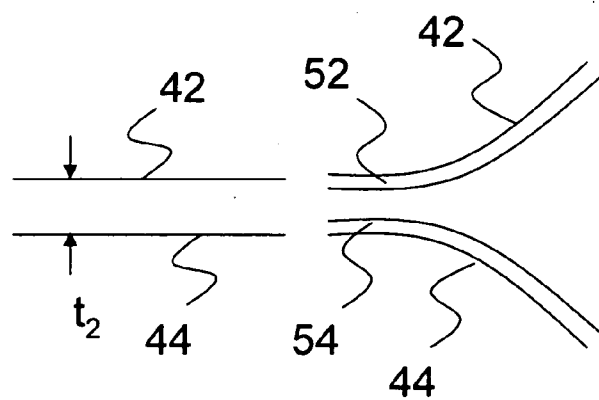


FIG. 2(d)

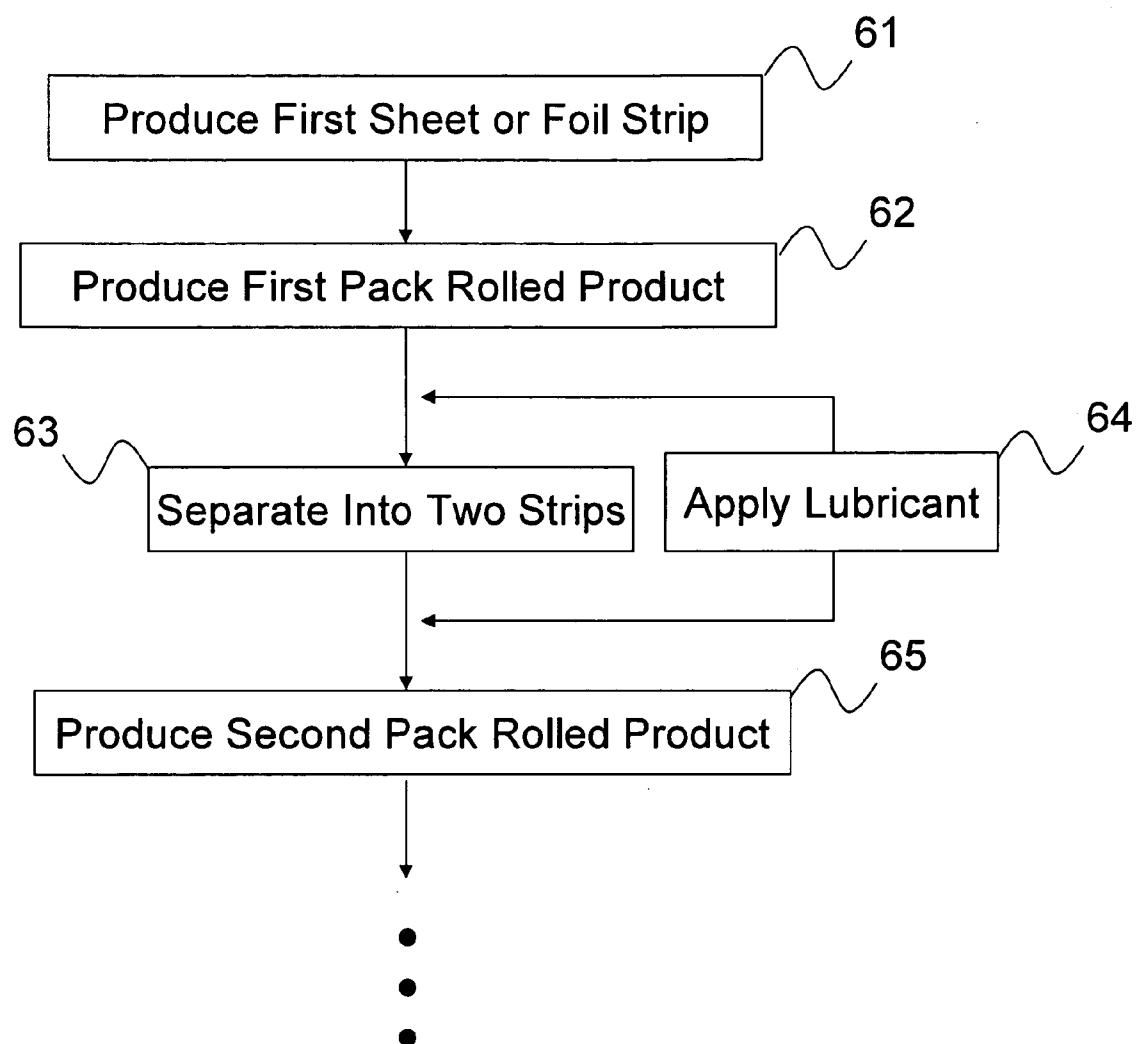


FIG. 3(a)

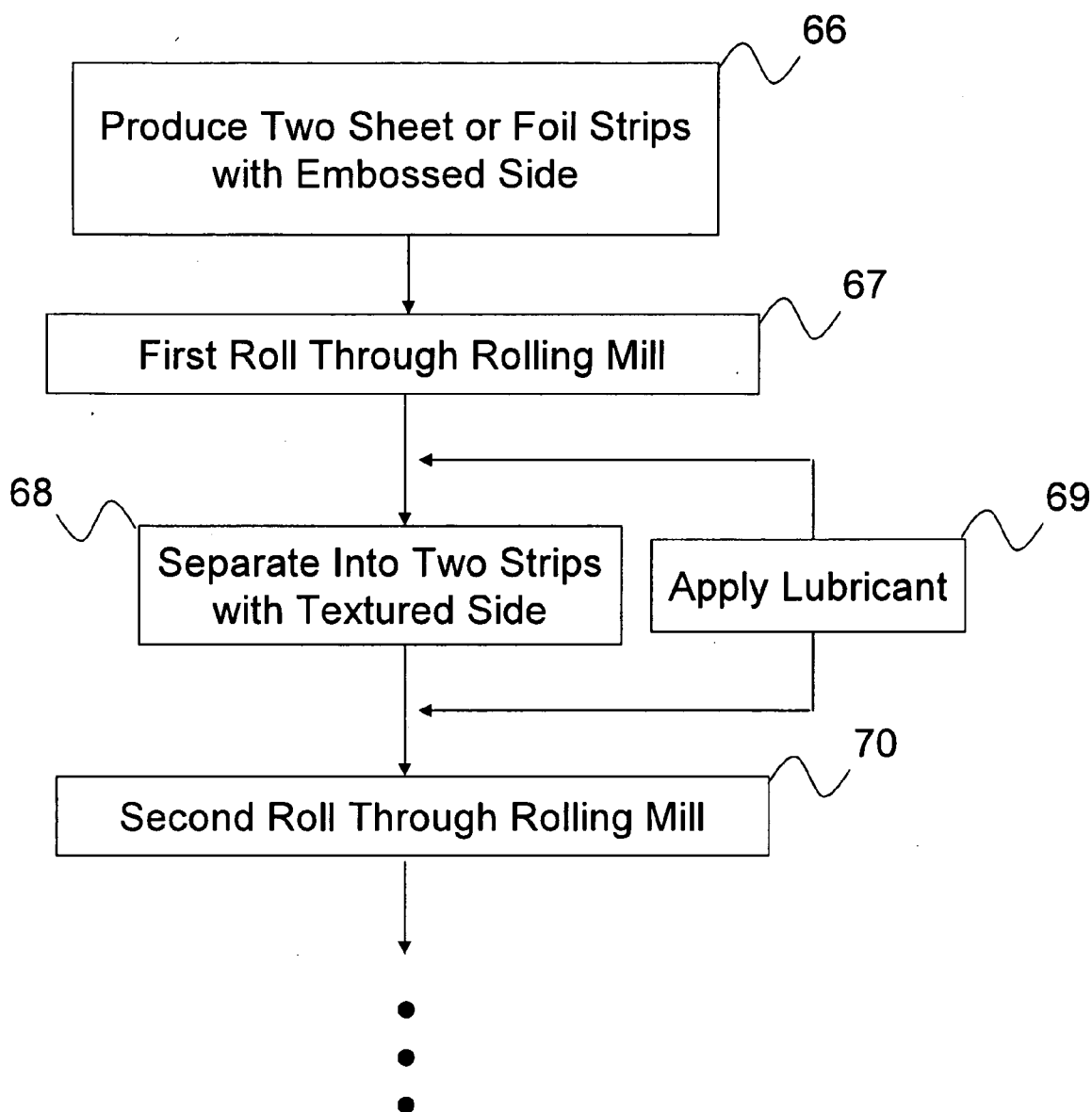
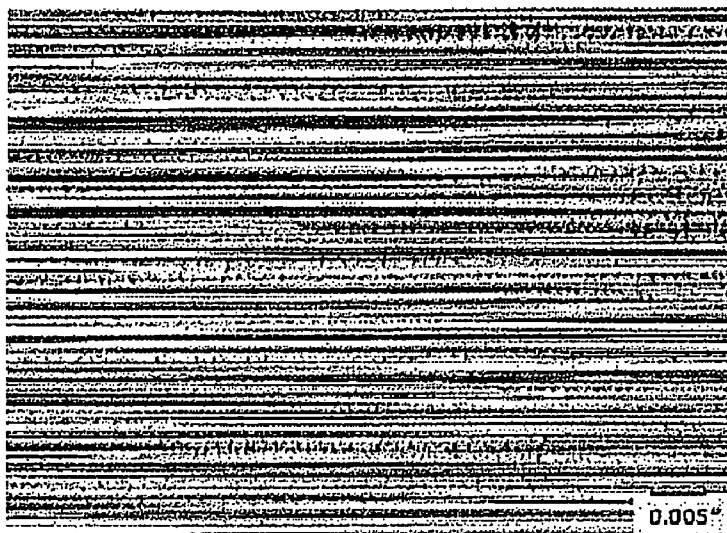
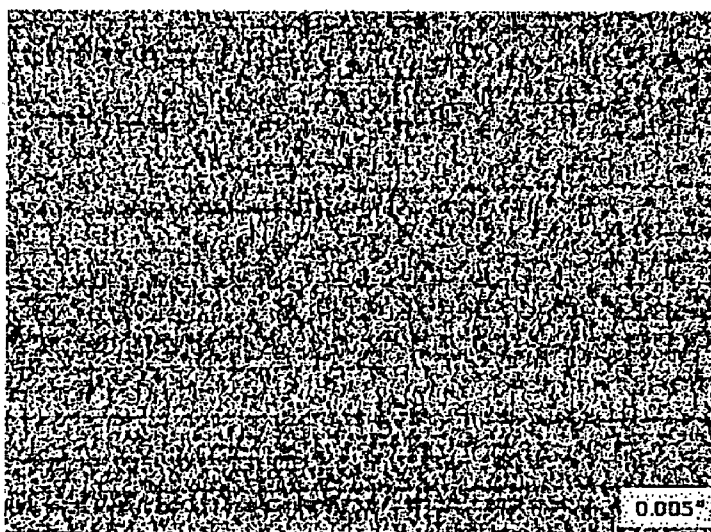


FIG. 3(b)

82

**FIG. 4(a)**

84

**FIG. 4(b)**

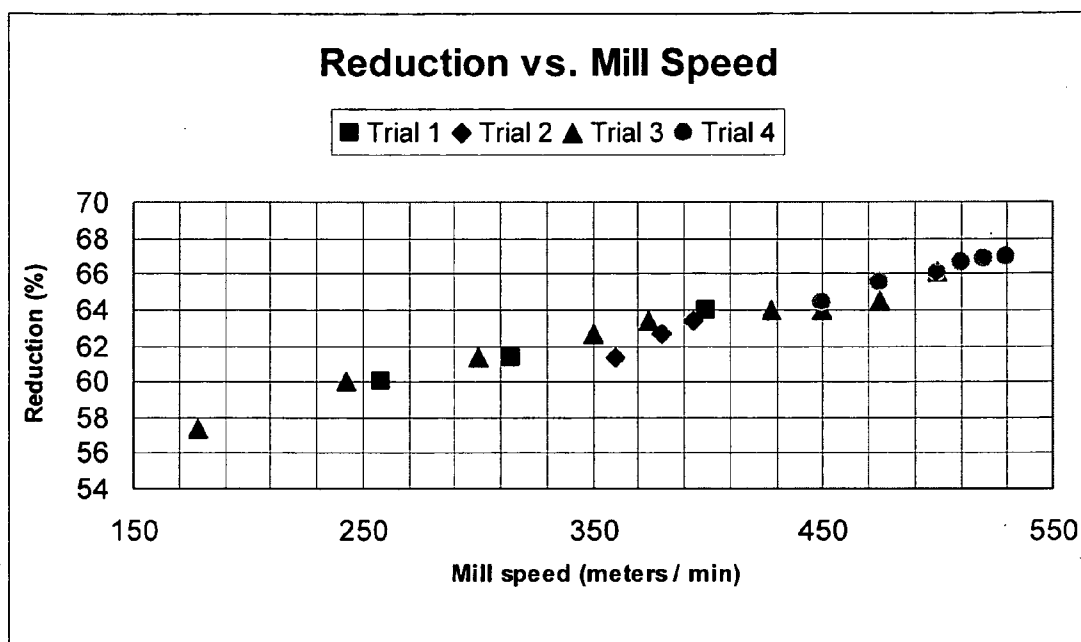


FIG. 5(a)

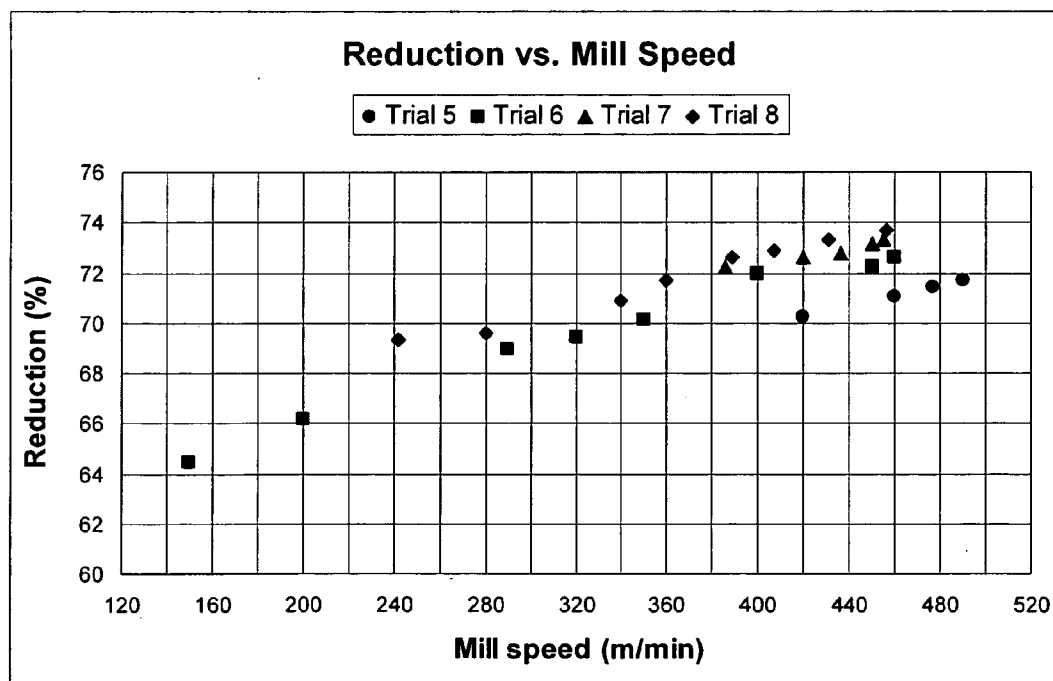


FIG. 5(b)

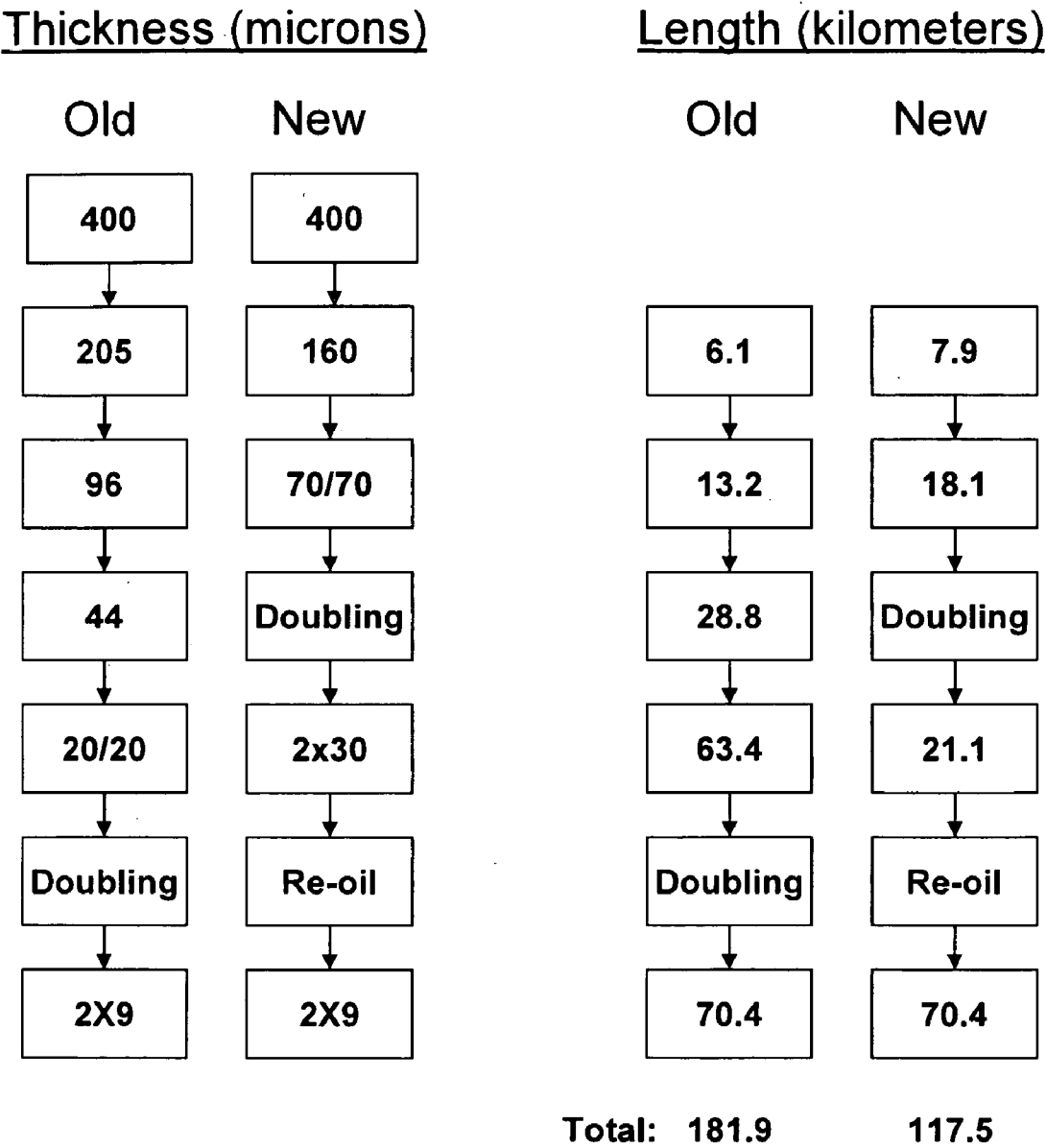


FIG. 6(a)

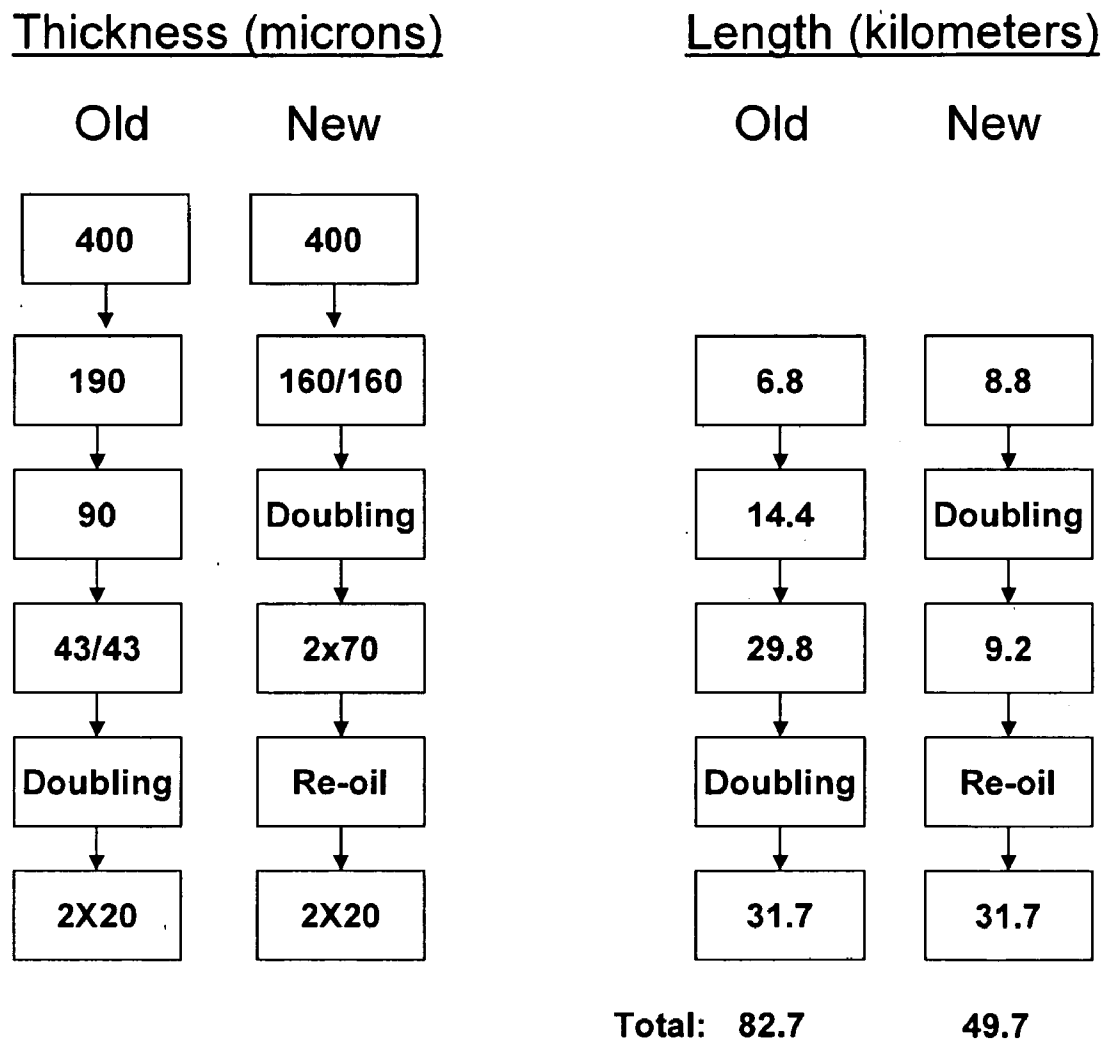


FIG. 6(b)

METHOD OF PRODUCING ALUMINUM PRODUCTS

BACKGROUND

[0001] Aluminum foil can be produced by rolling sheet ingots cast from molten aluminum, then re-rolling on sheet and foil rolling to the desired thickness, or by continuously casting and cold rolling. To maintain constant thickness in aluminum foil production, when the foil has become too thin, the rollers can apply less pressure thereby increasing film thickness. Alternatively, when the foil has become too thick, the rollers can apply more pressure thereby causing the foil to be made thinner. In these rolling modes, the actual reduction in thickness may be dependent on the lubricating regime of a rolling oil and the ability to maintain a stable oil film within the roll gap.

SUMMARY

[0002] Methods of increasing the reduction of foil thicknesses to minimize the number of passes through a sheet and foil rolling mill are disclosed. One embodiment discloses a method comprising: (a) producing a first pack rolled aluminum product having a first side and a second side and a first thickness; (b) separating the first pack rolled aluminum product into a first strip and a second strip, wherein the first strip is associated with the first side and a third side, and wherein the second strip is associated with the second side and a fourth side; and (c) rolling the first strip and the second strip into a second pack rolled aluminum product, wherein the rolling comprises: (i) contacting the first side of the first strip with the second side of the second strip; (ii) contacting the third side of the first strip with a first work roll; (iii) contacting the fourth side of the second strip with a second work roll; and wherein after the rolling step (c), the thickness of the second pack rolled aluminum product is at least about 65% less than the first thickness of the first pack rolled aluminum product. In one embodiment, the rolling step (c) comprises: concomitant to the contacting step (c)(i), lubricating at least one of the first side of the first strip and the second side of the second strip with a lubricant.

[0003] In one embodiment, the method further comprises: (d) separating, after the rolling step (c), the second pack rolled aluminum product into the first strip and the second strip, wherein the separating step (d) occurs in the absence of welding between the first strip and the second strip. The aluminum products produced by the presently disclosed embodiments include aluminum foils and aluminum sheets. In one embodiment, before the rolling step (c), the first side and the second side have bright finishes and the third side and the fourth side have matte finishes. In one embodiment, the thickness of the first pack rolled aluminum product is not greater than about 0.2 mm, wherein after the rolling step (c), the thickness of the second pack rolled aluminum product is equal to or at least about 65% less than the thickness of the first pack rolled aluminum product.

[0004] One embodiment discloses a method comprising: (a) producing a first strip having a first embossed side and a third side; (b) producing a second strip having a second embossed side and a fourth side; (c) rolling the first strip and the second strip into a pack rolled aluminum product, wherein the rolling comprises: (i) contacting the third side of the first strip with the fourth side of the second strip; (ii) contacting the first embossed side of the first strip with a first work roll; (iii)

contacting the second embossed side of the second strip with a second work roll; and (d) separating the pack rolled aluminum product into the first strip and the second strip; wherein the thicknesses of the first and second strips after the rolling step (c) are at least about 65% less than the thicknesses of the first and second strips before the rolling step (c), respectively. In one embodiment, the rolling step (c) comprises: concomitant to the contacting step (c)(i), lubricating at least one of the third side of the first strip and the fourth side of the second strip with a lubricant. In one embodiment, the separating step (d) occurs in the absence of welding between the first strip and the second strip. The aluminum products produced by the presently disclosed embodiments include aluminum foils or aluminum sheets. In one embodiment, before the rolling step (c), the third and fourth sides can have bright or matte finishes.

[0005] One embodiment discloses a method comprising: (a) producing a first pack rolled aluminum product having a first side and a second side and a first thickness; (b) separating the first pack rolled aluminum product into a first strip and a second strip, wherein the first strip is associated with the first side and a third side, and wherein the second strip is associated with the second side and a fourth side; and (c) rolling the first strip and the second strip into a second pack rolled aluminum product, wherein the rolling comprises: (i) contacting the first side of the first strip with the second side of the second strip; (ii) contacting the third side of the first strip with a first work roll; (iii) contacting the fourth side of the second strip with a second work roll; and (d) separating the second pack rolled aluminum product into the first strip and the second strip in the absence of welding, wherein the thicknesses of the first and second strips after the rolling step (c) are at least about 65% less than the thicknesses of the first and second strips before the rolling step (c), respectively. In one embodiment, the rolling step (c) comprises: concomitant to the contacting step (c)(i), lubricating at least one of the first side of the first strip and the second side of the second strip with a lubricant. Any of the above embodiments may comprise producing aluminum foils or aluminum sheets.

[0006] In one embodiment, the lubricant comprises a rolling oil, wherein the rolling oil includes C10 to C16 paraffin and kerosene. In other embodiments, the lubricant includes an additive, and wherein the additive is at least one of a fatty acid, alcohol, and an ester, and wherein: the fatty acid includes C12 to C18 oleic, stearic and isostearic compounds; the alcohol includes C12 to C16 compounds; and the ester includes methyl laurate, butyl ester and TMP ester.

[0007] Other variations, embodiments and features of the present methods will become evident from the following detailed description, drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a diagram of one embodiment of a sheet and foil rolling mill;

[0009] FIGS. 2(a)-2(d) are processing steps of producing an aluminum product according to an embodiment of the present disclosure;

[0010] FIGS. 3(a)-3(b) are flow diagram of methods of producing an aluminum product according to some embodiments;

[0011] FIGS. 4(a)-4(b) are images of bright and matte finishes, respectively;

[0012] FIGS. 5(a)-5(b) are spreadsheets illustrating percentage reductions versus mill speeds of various test trial results using embodiments of the presently disclosed methods; and

[0013] FIGS. 6(a)-6(b) are block diagrams illustrating thickness reductions and length efficiencies using the rolling passes according to some embodiments of the presently disclosed methods.

DETAILED DESCRIPTION

[0014] It will be appreciated by those of ordinary skill in the art that the presently disclosed methods can be embodied in other specific forms without departing from the spirit or essential character thereof. The presently disclosed embodiments are therefore considered in all respects to be illustrative and not restrictive.

[0015] FIG. 1 illustrates a sheet and foil rolling mill 10 having a mill housing 11 with work rolls 12 and associated backup rolls 13. As used herein, “work roll” 12 and the like is a roller disposed about a rolling mill 10 that comes in contact with the material to be rolled. For example, the work roll 12 may contact a sheet or foil product. Generally, as an aluminum sheet or foil passes through the work rolls 12, it can be squeezed thinner and extruded through the gap between the work rolls 12. The work rolls 12 are paired with the heavier backup roll 13, which apply pressure to help maintain stability of the work rolls 12. In one embodiment, the backup rolls 13 also help to hold the product dimensions within tolerances (e.g., maintain constant thickness in aluminum sheet or foil production). Hydraulics 14 may be incorporated to facilitate operation of the rolls 12, 13 in the directions as shown.

[0016] The reduction of the sheet or foil may be controlled by adjusting the meters per minute (mpm) of the rolls 12, 13 and the viscosity (the resistance to flow), quantity, and temperature of the rolling lubricants, which may be added to facilitate the rolling process. The lubricants may be applied to the rolls 12, 13 by spraying nozzles 15(a) disposed substantially adjacent the rolls 12, 13. In some embodiments, lubricants may be applied to the sheet or foil using sprayers or applicators 15(b) disposed substantially adjacent a coil of sheet or foil 16(a) as it unrolls and is about to enter the rolling mill 10. In some embodiments, the lubricant may be applied concomitantly to the sheet or foil prior to entering 16(a) the rolling process or after exiting 16(b) the rolling mill 10. As used herein, “lubricant” and the like means a substance (often a liquid) introduced between two moving surfaces to reduce friction. For example, a lubricant may be used to mitigate or even restrict or eliminate the welding of two strips of sheet or foil 16 during a rolling step. In one embodiment, the lubricant includes a rolling oil, wherein the rolling oil includes C10 to C16 paraffin and/or kerosene.

[0017] The gap and pressure between the work rolls 12 at least assist in determining the thickness and/or length of the sheet or foil leaving 16(b) the mill 10. This gap can be adjusted by raising or lowering one or both of the work rolls 12. In one embodiment, under contacting rolling mode, the work rolls 12 may be touching the outside or width of a rolled product and pressure may be maintained therewith. As used herein, a “bright finish” is produced when the sheet or foil 16(a) comes in contact with the surface of the work roll 12 while a “matte finish” is produced when two sheets or foils 16(a) are packed together and rolled simultaneously. Generally, after a rolling step, the sides that are touching each other end up with matte finishes while the sides that are touching

the surfaces of the work roll 12 end up with bright finishes. This will become more apparent in subsequent figures and discussion.

[0018] A “bright finish” may result in partial duplication of the work roll surface morphology. In addition, the bright finish may contain microscopic channels that facilitate lubricant flow backward. A “matte finish” may result in an isotropic surface morphology, and may be configured to trap lubricant during the foil rolling process. “Isotropic” and the like means the same or similar characteristics or uniformity in most or all directions. “Work roll surface” and the like means a surface that has been ground with an abrasive wheel or rotary abrasive belt or other suitable abrasive material so as to produce an elongated surface with elongated scratches, as opposed to a textured surface composed of isotropic pits. For example, a work roll surface can be conventional (un-textured), embossed or textured (e.g., depressions, craters, and other surface morphologies formed by rolling, grinding, polishing and sand blasting).

[0019] The presently disclosed methods can be carried out on rolls having surface roughness R_a of about 0.08 to about 0.29 micron. In two examples, the double-rolling method can be carried out on rolls having surface roughness R_a of about 0.09 micron and 0.14 micron. In one embodiment, the methods can be carried out on rolls having surface roughness R_a less than about 0.08 micron or greater than about 0.29 micron. Rougher rolls may be less efficient during the rolling process while the smoother rolls may be more efficient. In other words, a roll with a higher surface roughness R_a may have lower percentage of reduction compared to another roll of similar thickness but with lower surface roughness R_a . Accordingly, the amount of reduction may be a combination of several factors including mill speed, surface roughness, and initial thickness of the film, to name a few.

[0020] The sheet and foil rolling mill 10 further includes a gauge meter 17 for measuring the thickness of the sheet or foil 16(b). As used herein, “thickness” relative to an aluminum product (e.g., pack rolled aluminum product or strip) and the like means the thickness of an aluminum product as measured by a micrometer or digital caliper in accordance with techniques used by the National Institute of Standards and Technology. In some embodiments, the aluminum products include aluminum foils and aluminum sheets, the aluminum products composed of aluminum or aluminum alloy of 1xxx, 2xxx, 3xxx, 4xxx, 5xxx, 6xxx, 7xxx and 8xxx series. In one embodiment, other types of aluminum alloys may also be incorporated. As used herein, “aluminum foil” means an aluminum product having a thickness of not greater than about 200 microns, and “aluminum sheet” means an aluminum product having a thickness of at least about 201 microns and not greater than about 0.249 inches (about 6324 microns).

[0021] The sheet and foil rolling mill 10 may also include a flatness roll 18 for measuring the flatness of the product or making the sheet or foil 16(b) more uniform when it exits the rolls 12, and an ironing roll 19 for smoothing or uniformly coiling the sheet or foil 16(b). As shown, the aluminum sheet or foil 16(b) can be wound into coil form. In one embodiment, the aluminum sheet or foil 16(b) exiting the rolling mill 10 need not be wound into a coil.

[0022] A reduction in film thickness can be accomplished by means of rolling from continuous cast or hot rolled aluminum coils with initial foil gauges of from about 2 mm to about 10 mm down to final foil gauges of from about 0.006 mm to about 0.2 mm. In one embodiment, different passes can be

made in heavy gauge cold rolling mills **10** to provide cold rolled foil stock coils. The coils can subsequently be transferred to foil mills **10** at thicknesses of from about 0.2 mm to about 1 mm and continued rolling to final foil gauges. As used herein, “continuous cast” means a fabrication process produced by rolling sheet ingots cast from molten aluminum and then re-rolling on sheet and foil rolling mills to the desired thickness. “Hot rolling” or “hot rolled” and the like means a fabrication process in which the aluminum product is heated above its recrystallization temperature and then deformed between rollers to form thinner cross sections. “Cold rolling” or “cold rolled” and the like means a fabrication process produced in which the aluminum product is deformed by passing it through rollers at a temperature below its recrystallization temperature.

[0023] FIGS. 2(a)-2(d) illustrate processing steps of producing an aluminum product according to an embodiment of the present disclosure. FIG. 2(a) illustrates a first pack rolled aluminum product **20** having a first side **22**, a second side **24**, and an initial thickness t_1 . The first pack rolled aluminum product **20** can be provided from a third party or produced via a manufacturing process described below. As used herein, “pack rolled aluminum product” and the like means two sheets passed together through the nip of rollers resulting in two sheets each having a bright surface (that came in contact with a surface of a roller) and a matte surface. “Producing a pack rolled aluminum product” and the like means any suitable rolling processes configured to produce at least aluminum foil and/or aluminum sheet products. For example, the producing step may include continuous cast, hot rolling and cold rolling. In one embodiment, the first pack rolled aluminum product **20** is wound into a coil, although it is not necessary to do so. In one embodiment, the two sides **22**, **24** have bright finishes. In other embodiments, the two sides **22**, **24** have matte finishes. In the alternative, there can be a mix of finishes for the two sides **22**, **24**.

[0024] FIG. 2(b) illustrates the first side **22** and the second side **24** of the first pack rolled aluminum product **20** being separated into a first strip **32** and a second strip **34**, wherein the first strip **32** is associated with the first side **22** and a third side **42**, while the second strip **34** is associated with the second side **24** and a fourth side **44**. As used herein, “strip” and the like means a piece of material in which the length is many times its width, and “separating a pack rolled aluminum product” and the like means the act of dividing or detaching the pack rolled aluminum product. For example, the separating step may include trimming and slitting. “Trimming” and the like means cutting the edges of the aluminum sheet or aluminum foil with circular or razor-like knives installed on a rolling mill, while “slitting” and the like means cutting the aluminum product into several aluminum sheets or aluminum foils with circular or razor-like knives installed on a rolling mill. As shown, lubricant can be applied to the one or more of sides **22**, **24**, **42**, **44** as the strips **32**, **34** exit the separation process.

[0025] FIG. 2(c) illustrates the strips **32**, **34** being rolled through the mill **10** via work rolls **12** to form a second pack rolled aluminum product **30** having a second thickness t_2 , wherein the rolling step includes contacting the first side **22** of the first strip **32** with the second side **24** of the second strip **34**, contacting the third side **42** of the first strip **32** with a first work roll **12(a)**, and contacting the fourth side **44** of the second strip **34** with a second work roll **12(b)**. As used herein, “rolling” and the like means fabrication process in which a

material is passed through a pair (or pairs) of rollers or work rolls. For example, the rolling step may include hot rolling or cold rolling an aluminum product to produce sheet and foil. “Contacting” and the like means in direct physical contact with. In addition, lubricant can be applied to the one or more of sides **22**, **24**, **42**, **44** as the strips **32**, **34** enter the rolling mill **10**. One result of the rolling step is that the thickness t_2 of the second pack rolled aluminum product **30** may be at least about 65% less than the thickness t_1 of the first pack rolled aluminum product **20**. In other embodiments, the reduction in thickness may be at least about 70%, or at least about 72%, or at least about 75%, or at least about 78%, or at least about 80%. The rolling process in which two strips **32**, **34** are rolled through a rolling mill **10** may be performed by at least two types of apparatus. First, the use of a doubling machine, which prepares a coil **20** with two strips **32**, **34** that can be later fed into the rolling mill **10**. Second, the use of double uncoiler rolling mills **10** where two strips **32**, **34** are uncoiled at the same time and simultaneously fed to the rolls **12(a)**, **12(b)**.

[0026] In one embodiment, the first side **22** of the first strip **32** and the second side **24** of the second strip **34** have bright finishes while the third side **42** of the first strip **32** and the fourth side **44** of the second strip **34** have matte finishes. In other embodiments, there can be a mixture of finishes. For example, both the first and second sides **22**, **24** can have matte finishes, or one side can be bright and the other side can be matte. Likewise, both the third and fourth sides **42**, **44** can have bright finishes, or one side can be bright and the other can be matte. In one embodiment, the thickness t_1 of the first pack rolled aluminum product **20** is not greater than about 0.2 mm, wherein after the rolling step of FIG. 2(c), the thickness t_2 of the second pack rolled aluminum product **30** is equal to or at least about 65% less than the thickness t_1 of the first pack rolled aluminum product **20**. In other embodiments, the reduction in thickness may be at least about 70%, or at least about 72%, or at least about 75%, or at least about 78%, or at least about 80%.

[0027] FIG. 2(d) illustrates the second pack rolled aluminum product **30**, being substantially a single strip with the third and fourth sides **42**, **44** on the outsides, and can be further separated into two strips **52**, **54** by the separation techniques previously described. In one embodiment, the second pack rolled aluminum product **30** can be wound into a coil as shown in FIG. 2(c). In one embodiment, the second pack rolled aluminum product **30** can be separated into two separate strips **52**, **54** as shown in FIG. 2(d). For example, the double rolled coil **30** can be cut into dimension in a separator machine, which separates the two strips **52**, **54**. In one embodiment, the two strips **52**, **54** can be further processed through the rolling step as previously described or additional rolling or separation processing steps (not shown).

[0028] In one embodiment, the first pack rolled aluminum product **20** starts with a thickness t_1 of about 40 microns with each strip **32**, **34** of the first pack rolled aluminum product **20** having a thickness of about 20 microns after the separation step. After the rolling step, the resulting second pack rolled aluminum product **30** may have a thickness t_2 of not greater than about 12 microns or a reduction in thickness of at least about 70%. The second pack rolled aluminum product **30** can be further separated by the methods previously described into two strips **52**, **54** as shown in FIG. 2(d), with each strip **52**, **54** having a thickness of about 6 microns.

[0029] In one embodiment, the second separating step as shown in FIG. 2(d) occurs in the absence of welding between the two strips 52, 54. As used herein, “absence of welding” and the like means the lack of joining (e.g., permanent joining) of two pieces of material by fusion, for example, lack of joining of the two pieces by heat or pressure. To restrict welding, a lubricant may be applied concomitantly during the step of contacting the first side 22 of the first strip 32 with the second side 24 of the second strip 34. In some embodiments, the lubricant includes an additive. In some embodiments, the additive is at least one of a fatty acid, alcohol, and an ester. In some embodiments, the fatty acid includes C12 to C18 oleic, stearic and isostearic compounds. In some embodiments, the alcohol includes C12 to C16 compounds. In some embodiments, the ester includes methyl laurate, butyl ester and TMP ester.

[0030] FIG. 3(a) is a flow diagram of a method of producing an aluminum product according to one embodiment of the present disclosure. In one embodiment, two sheet or foil strips are produced 61, wherein each strip may be associated with a bright finish and a matte finish. After the two strips are produced 61, the product may be subjected to a first double roll step to produce a first pack rolled product 62. In one embodiment, the bright sides are in contact with the work rolls while the matte sides are in contact with each other. For example, the bright finish of a first strip can contact a first work roll, while the bright finish of a second strip can contact a second work roll. In some embodiments, oils or lubricants may be applied to the matte finishes. The two sheet or foil strips may be separated 63 after the first double roll step 62. The reduction in thickness of each of the separated strips 63 can range from about 40% to about 60%.

[0031] After the strips have been separated 63, they may again be subjected to a second double roll step to produce a second pack rolled product 65. In one embodiment, the matte side of the strips are making contact with the work rolls. For example, a first matte side of a first strip may contact a first work roll while a second matte side of a second strip may contact a second work roll. The sides opposite the matte finishes of each strip may have bright finishes, and would be making contact with each other. In other words, a first bright side of a first strip may contact a second bright side of a second strip. Lubricants 64 similar to those described above may be dispensed concomitantly on the strips of foil or sheet. In one embodiment, the lubricant may be applied 64 while or after the first pack rolled aluminum product is being separated into two strips 63. In one embodiment, the lubricant may be applied 64 prior to the bright sides of each strip making contact with each other and the matte sides making contact with the work rolls to produce a second pack rolled product 65. The reduction in thickness of each strip of the second pack rolled product may be at least about 65%. In one embodiment, the reduction in thickness can range from about 65% to about 80%.

[0032] In one embodiment, the lubricant may bring about an absence of welding between the strips. In one embodiment, the lubricant includes an additive. In one embodiment, the additive is at least one of a fatty acid, alcohol, and an ester. In one embodiment, the fatty acid includes C12 to C18 oleic, stearic and isostearic compounds. In one embodiment, the alcohol includes C12 to C16 compounds. In one embodiment, the ester includes methyl laurate, butyl ester and TMP ester.

[0033] The second pack rolled product may subsequently be separated into two strips, applied with additional lubricant,

and rolled through a third set of work rolls to produce a third pack rolled product (not shown). In other words, the rolling processes may be repeated as many times as necessary to achieve additional thickness reductions.

[0034] FIG. 3(b) is a flow diagram of a method of producing an aluminum product according to one embodiment of the present disclosure. In one embodiment, two sheet or foil strips are produced 66, wherein each strip may be associated with an embossed side, the “embossed” and the like means having text, design or decoration raised above or below its surface. In the alternative, the strips may be textured or laminated, which allows a first roughened or textured strip of foil to be coupled to a second strip of foil or sheet and rolled through the work rolls. The side opposite the embossed or textured side may have bright or matte finishes. The embossed texture may improve lubricant retention in the roll gap, which can allow a high degree of reduction. In other words, the embossment may function similar to that of the matte finish. The use of matte finishes contacting work rolls can help to retain the lubricant because of its isotropic surface appearance.

[0035] In one embodiment, work rolls may be textured or embossed to produce similar lubricant retaining effect as that of the strips having matte finishes, or embossed or textured finishes. In one embodiment, skin pass texturing can be carried out on the work rolls including lamination to produce textured or embossed work rolls.

[0036] In one embodiment, texture can be applied to both surfaces of a single sheet or foil (not shown) that may subsequently be rolled without doubling and with a reduction in thickness of at least about 65%. In other words, the rolling need not be carried out on two or more strips of sheet or foil but a single sheet or foil may be rolled through the work rolls and achieve at least about 65% of reduction in thickness.

[0037] After the two strips have been produced 66, the product may be rolled through a rolling mill in a first rolling pass 67. In one embodiment, the first rolling step 67 may produce a first pack rolled aluminum product, the aluminum product being aluminum foil or aluminum sheet. In one embodiment, the first rolling step 67 involves contacting the embossed side of the first strip with a first work roll, contacting the embossed side of the second strip with a second work roll, and contacting the surfaces opposite the embossed sides with each other. In one embodiment, the sides opposite the embossment may have bright finishes and be in contact with the work rolls. In one embodiment, alternating surfaces may make contact with the work rolls. In other words, an embossed finish of a first strip can contact a first work roll, while a matte finish of a second strip can contact a second work roll, or a bright finish of a first strip can contact a first work roll, while an embossed finish of a second strip can contact a second work roll. In some embodiments, various configurations of surfaces touching work rolls and each other are possible.

[0038] After the first rolling step 67, the product may be separated into two strips 68. In one embodiment, each strip may have a textured side. The reduction in thickness of each of the separated strips can range from about 65% to about 80%. The separated strips may subsequently be rolled through a rolling mill in a second rolling pass 70. The reduction in thickness through the second rolling pass 70 can also range from about 65% to about 80%. The second rolling pass 70 may be carried out with the textured finishes touching the work rolls and the opposite sides touching each other. Lubricants similar to those discussed above may be applied 69

concomitantly to the separating step 68. In one embodiment, the lubricant may be applied 69 to the textured sides of the separated strips. In one embodiment, the lubricant may be applied 69 to the side opposite the textured sides of the separated strips. In one embodiment, the lubricant comprises a rolling oil, wherein the rolling oil includes C10 to C16 paraffin and kerosene. In some embodiments, the lubricant comprises an additive, wherein the additive is at least one of a fatty acid, alcohol and an ester. In one embodiment, the fatty acid includes C12 to C18 oleic, stearic and isostearic compounds. In one embodiment, the alcohol includes C12 to C16 compounds. In one embodiment, the ester includes methyl laurate, butyl ester and TMP ester.

[0039] In some embodiments, the method may consist of one or more of the steps described above.

[0040] FIG. 4(a) shows a foil surface having a bright finish 82 as a result of being in contact with a work roll surface 12 during the rolling process. The resulting image shows microscopic channels (horizontal streaks or linear striations), which is a partial duplication of the work roll surface morphology and can facilitate lubricant flow backward due to high backward pressure gradient in front of a roll bite (nip or interface between work roll surface and foil). FIG. 4(b) shows a foil surface having a matte finish 84, which has an isotropic morphology because the aluminum grain can freely move during deformation. The isotropic foil surface morphology enables the trapping of adequate amount of lubricant in the interface between foil and work roll surfaces 12. Lubricant can be released from these trapped cavities on the matte foil surfaces 84 and can be used to lubricate surrounding areas at the roll and foil interface resulting in the absence of welding between the strip and the roll and forming a stable lubricant film that allows metal deformation and produces desired the desired surface quality. As such, the strips are able to achieve thickness reduction of at least about 65% compared with conventional reduction of about 50% or about 55%. In one embodiment, the matte finish 84 can be mimicked or reproduced by embossing or texturing techniques. As used herein, “embossed” and the like means having text, design or decoration raised above or below its surface. This can be accomplished by electrical or mechanical apparatus and devices causing an indentation, text, design or decoration above or beneath the surface of the strip of aluminum sheet or aluminum foil.

[0041] FIGS. 5(a)-5(b) illustrate a plurality of test trial results using one of the embodiments described above, wherein two strips of foils are double rolled with matte sides touching work rolls, and bright sides touching each other and lubricant applied therein. As shown, the x-axis identifies the mill speed (meters per minute) while the y-axis identifies the percentage reduction as calculated using the following equation: $[(\text{initial film thickness} - \text{final film thickness}) / (\text{initial film thickness})] \times 100\%$. For example, if a strip of aluminum product prior to entering a rolling process has an initial thickness of about 50 microns and a final thickness of about 22 microns exiting the rolling process, the percentage reduction equals: $[(50 \text{ microns} - 22 \text{ microns}) / (50 \text{ microns})] \times 100\%$, or about 56% reduction.

[0042] The test results of FIG. 5(a) illustrate reduction in thickness using standard interleaving oil as a lubricant. The interleaving oil may be a rolling oil having C10 to C16 paraffin and kerosene. The initial film thickness for the various test trials is about two times 37.5 microns with a surface roughness R_a of about 0.14 micron. In trial 1, the films are

rolled at mill speeds of about 258 mpm to about 400 mpm producing total film thicknesses of about 27 microns to about 30 microns resulting in reductions of about 60% $\{[(2 \times 37.5 \text{ microns} - 30 \text{ microns}) / (2 \times 37.5 \text{ microns})] \times 100\%$ to about 64% $\{[(2 \times 37.5 \text{ microns} - 27 \text{ microns}) / (2 \times 37.5 \text{ microns})] \times 100\%$. In trial 2, the films are rolled at mill speeds of about 360 mpm to about 394 mpm producing total film thicknesses of about 27.5 microns to about 29 microns resulting in reductions of about 61.3% to about 63.3%. In trial 3, the films are rolled at mill speeds of about 178 mpm to about 500 mpm producing total film thicknesses of about 25.4 microns to about 32 microns resulting in reductions of about 57.3% to about 66.1%. In trial 4, the films are rolled at mill speeds of about 450 mpm to about 530 mpm producing total film thicknesses of about 24.8 microns to about 26.7 microns resulting in reductions of about 64.4% to about 66.9%. Based on the results of these trial runs, a mill speed of about 250 meters per minute may achieve a thickness reduction of at least about 60%. As the mill speed increases, the percentage of reduction increases. For example, a thickness reduction of at least about 65% may be achieved at a mill speed of about 490 meters per minute. For trial runs 1-4, rolling oil with C14 linear paraffin are utilized without any additives. Some welding between the strips are observed for trial runs 1-4.

[0043] Other test runs are illustrated in FIG. 5(b). These test runs illustrate an absence of welding where at least one additive is employed. The initial film thickness for the various test trials is about two times 38 microns with a surface roughness R_a of about 0.09 micron. In trial 5, the films are rolled at mill speeds of about 420 mpm to about 490 mpm producing total film thicknesses of about 21.5 microns to about 22.6 microns resulting in reductions of about 70.3% $\{[(2 \times 38 \text{ microns} - 22.6 \text{ microns}) / (2 \times 38 \text{ microns})] \times 100\%$ to about 71.7% $\{[(2 \times 38 \text{ microns} - 21.5 \text{ microns}) / (2 \times 38 \text{ microns})] \times 100\%$. In trial 6, the films are rolled at mill speeds of about 150 mpm to about 460 mpm producing total film thicknesses of about 20.8 microns to about 27 microns resulting in reductions of about 64.5% to about 72.6%. In trial 7, the films are rolled at mill speeds of about 386 mpm to about 455 mpm producing total film thicknesses of about 20.3 microns to about 21.1 microns resulting in reductions of about 72.2% to about 73.3%. In trial 8, the films are rolled at mill speeds of about 242 mpm to about 456 mpm producing total film thicknesses of about 20 microns to about 23.3 microns resulting in reductions of about 69.3% to about 73.7%. Based on the results of these trial runs, a mill speed of about 160 meters per minute may achieve a thickness reduction of at least about 65%. As the mill speed increases, the percentage of reduction increases. For example, a thickness reduction of at least about 70% may be achieved at a mill speed of about 250 meters per minute. For trial runs 5-8, rolling oil with about 0.4% lauric acid and about 2% methyl laurate additives are utilized. No welding is observed between the strips for these runs.

[0044] Although not shown, mill speeds in excess of up to 1000 meters per minute, or 1200 meters per minute, or 1500 meters per minute, or 2000 meters per minute, may result in thickness reductions of at least about 65%.

[0045] FIG. 6(a)-6(b) are block diagrams illustrating thickness reductions and length efficiencies using the rolling passes according to some embodiments of the present disclosure. In FIG. 6(a), each block represents a film thickness after passing through a rolling mill with the exception of the starting film thickness (400 microns). Blocks labeled “Doubling” involves conventional doubling step, which can be accom-

plished in a doubling machine or rolling mill, while blocks labeled “Re-oil” involves the presently disclosed methods in which lubricant may be applied on bright surfaces of a first pack rolled product, and rolling the product through a doubling machine or rolling mill by contacting the matte surfaces to work rolls. With the old technique, it takes about five passes through the rolling mills to reduce 400 microns to 9 microns, with a doubling step in between. The reduction in thickness can range from about 48.8% to about 55.0%. For example, the reduction from about 400 microns to about 205 microns is about 48.8%, from about 205 microns to about 96 microns is about 53.2%, from about 96 microns to about 44 microns is about 54.2%, from about 44 microns to about 20 microns is about 54.5%, and from about 20 microns to about 9 microns is about 55.0%, in particular. In contrast, with the presently disclosed embodiments of re-oiling by applying lubricant on the bright surfaces of a first pack rolled product, and rolling the product through a doubling machine or rolling mill by contacting the matte surfaces to the work rolls, the presently disclosed embodiments are able to achieve substantially greater thickness reductions with four passes through the rolling mill. Utilizing the presently disclosed embodiments, the same 400 micron film may be reduced to 9 microns in four passes with a doubling step and a re-oil step. The amount of reduction ranges from about 56.3% (160 microns to 70 microns) to about 70% (30 microns to 9 microns). As such, the presently disclosed methods may be able to provide improved rolling mill efficiencies by eliminating at least about one rolling step relative to the conventional process.

[0046] In terms of length efficiencies, each block of rolled length corresponds to the thickness blocks. For example, a reduction of about 205 microns to about 96 microns translates to increased coil length from about 6.1 kilometers to about 13.2 kilometers, a reduction of about 96 microns to about 44 microns translates to increased coil length from about 13.2 kilometers to about 28.8 kilometers, and so forth. The longer the coils, the longer the time it takes to process through the rolling mill or doubling machine. To achieve a final length of about 70.4 kilometers of final thickness coil requires passing through the rolling mill at least about 181.9 kilometers length of coil using the traditional method, the 181.9 kilometers representing the sum of all lengths of coils being passed through the rolling mills in the five passes (6.1 km+13.2 km+28.8 km+63.4 km+70.4 km=181.9 km). In contrast, utilizing the presently disclosed methods, about 117.5 kilometers of coil are passed through the rolling mills to achieve the final length of about 70.4 kilometers (7.9 km+18.1 km+21.1 km+70.4 km=117.5 km). In one embodiment, this may translate to an improvement in mill productivity of about 40%.

[0047] FIG. 6(b) likewise illustrates one embodiment of thickness reduction and length efficiency using the presently disclosed methods in providing another film thickness (20 microns) and length (31.7 kilometers). In one embodiment, the standard process of reducing about 400 microns of coil to about 20 microns of coil requires four passes, with reduction in thickness ranging from about 52.2% to about 53.5%. In contrast, the presently disclosed methods allow the reduction of about 400 micron coil to about 20 micron coil in three passes with reduction percentages of about 56.3% to about 71.4%. Likewise, the amount of coil to be passed through the rolling machines can be reduced from about 82.7 kilometers using the traditional method to about 49.7 kilometers using the presently disclosed methods, which may translate into enhanced mill productivity.

[0048] Although the presently disclosed methods have been described in detail with reference to several embodiments, additional variations and modifications exist within the scope and spirit of the disclosure as described and defined in the following claims.

What is claimed is:

1. A method comprising:

- (a) producing a first pack rolled aluminum product having a first side and a second side and a first thickness;
- (b) separating the first pack rolled aluminum product into a first strip and a second strip, wherein the first strip is associated with the first side and a third side, and wherein the second strip is associated with the second side and a fourth side; and
- (c) rolling the first strip and the second strip into a second pack rolled aluminum product, wherein the rolling comprises:
 - (i) contacting the first side of the first strip with the second side of the second strip;
 - (ii) contacting the third side of the first strip with a first work roll;
 - (iii) contacting the fourth side of the second strip with a second work roll; and

wherein after the rolling step (c), the thickness of the second pack rolled aluminum product is at least about 65% less than the first thickness of the first pack rolled aluminum product.

2. The method of claim 1, wherein the rolling step (c) comprises:

concomitant to the contacting step (c)(i), lubricating at least one of the first side of the first strip and the second side of the second strip with a lubricant.

3. The method of claim 2, further comprising:

- (d) separating, after the rolling step (c), the second pack rolled aluminum product into the first strip and the second strip.

4. The method of claim 3, wherein the separating step (d) occurs in the absence of welding between the first strip and the second strip.

5. The method of claim 1, wherein the produced aluminum products include aluminum foils and aluminum sheets.

6. The method of claim 1, wherein before the rolling step (c), the first side and the second side have bright finishes and the third side and the fourth side have matte finishes.

7. The method of claim 1, wherein the thickness of the first pack rolled aluminum product is not greater than about 0.2 mm, wherein after the rolling step (c), the thickness of the second pack rolled aluminum product is equal to or at least about 65% less than the thickness of the first pack rolled aluminum product.

8. The method of claim 2, wherein the lubricant comprises a rolling oil, wherein the rolling oil includes C10 to C16 paraffin and kerosene.

9. The method of claim 2, wherein the lubricant includes an additive, and wherein the additive is at least one of a fatty acid, alcohol, and an ester, and wherein:

- the fatty acid includes C12 to C18 oleic, stearic and isostearic compounds;
- the alcohol includes C12 to C16 compounds; and
- the ester includes methyl laurate, butyl ester and TMP ester.

10. A method comprising:

- (a) producing a first strip having a first embossed side and a third side;

- (b) producing a second strip having a second embossed side and a fourth side;
- (c) rolling the first strip and the second strip into a pack rolled aluminum product, wherein the rolling comprises:
 - (i) contacting the third side of the first strip with the fourth side of the second strip;
 - (ii) contacting the first embossed side of the first strip with a first work roll;
 - (iii) contacting the second embossed side of the second strip with a second work roll; and
- (d) separating the pack rolled aluminum product into the first strip and the second strip; wherein the thicknesses of the first and second strips after the rolling step (c) are at least about 65% less than the thicknesses of the first and second strips before the rolling step (c), respectively.

11. The method of claim **10**, wherein the rolling step (c) comprises:

concomitant to the contacting step (c)(i), lubricating at least one of the third side of the first strip and the fourth side of the second strip with a lubricant.

12. The method of claim **10**, wherein the separating step (d) occurs in the absence of welding between the first strip and the second strip.

13. The method of claim **10**, wherein the produced aluminum products include aluminum foils and aluminum sheets.

14. The method of claim **10**, wherein before the rolling step (c), the third and fourth sides can have bright or matte finishes.

15. The method of claim **11**, wherein the lubricant comprises a rolling oil, wherein the rolling oil includes C10 to C16 paraffin and kerosene.

16. The method of claim **11**, wherein the lubricant includes an additive, and wherein the additive is at least one of a fatty acid, alcohol, and an ester, and wherein:

- the fatty acid includes C12 to C18 oleic, stearic and isostearic compounds;
- the alcohol includes C12 to C16 compounds; and
- the ester includes methyl laurate, butyl ester and TMP ester.

17. A method comprising:

- (a) producing a first pack rolled aluminum product having a first side and a second side and a first thickness;
- (b) separating the first pack rolled aluminum product into a first strip and a second strip, wherein the first strip is associated with the first side and a third side, and wherein the second strip is associated with the second side and a fourth side; and
- (c) rolling the first strip and the second strip into a second pack rolled aluminum product, wherein the rolling comprises:
 - (i) contacting the first side of the first strip with the second side of the second strip;
 - (ii) contacting the third side of the first strip with a first work roll;
 - (iii) contacting the fourth side of the second strip with a second work roll; and
- (d) separating the second pack rolled aluminum product into the first strip and the second strip in the absence of welding, wherein the thicknesses of the first and second strips after the rolling step (c) are at least about 65% less than the thicknesses of the first and second strips before the rolling step (c), respectively.

18. The method of claim **17**, wherein the rolling step (c) comprises:

concomitant to the contacting step (c)(i), lubricating at least one of the first side of the first strip and the second side of the second strip with a lubricant.

19. The method of claim **17**, wherein the produced aluminum products include aluminum foils and aluminum sheets.

20. The method of claim **18**, wherein the lubricant includes an additive, and wherein the additive is at least one of a fatty acid, alcohol, and an ester, and wherein:

- the fatty acid includes C12 to C18 oleic, stearic and isostearic compounds;
- the alcohol includes C12 to C16 compounds; and
- the ester includes methyl laurate, butyl ester and TMP ester.

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